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(54) **Drying apparatus**

(57) The drying apparatus comprises a drying chamber (11) connected in an air circulation circuit which has a branch loop (13) outside the chamber. A heating element (14) is associated with the air circuit while condensing means (15) are associated with the branch loop. The circulation of air in the branch loop is caused by a regulating element (17) sensitive to the temperature and/or humidity within the drying chamber.

FIG. 3

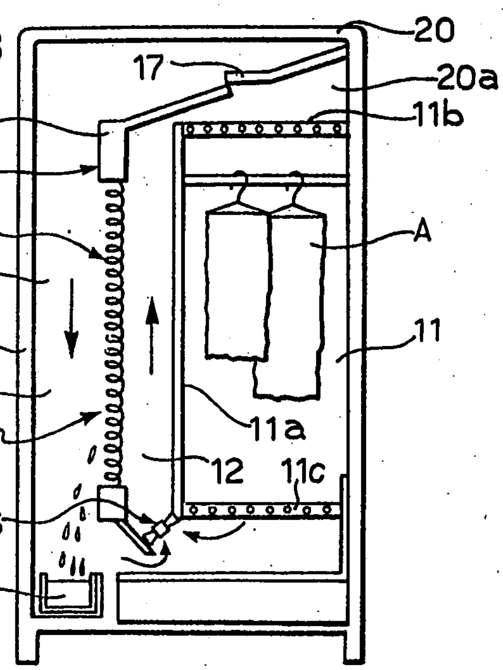

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FIG. 1

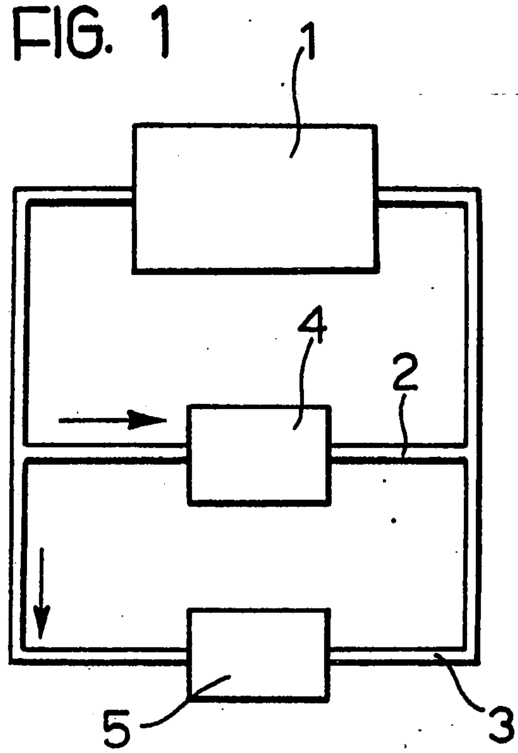


FIG. 2

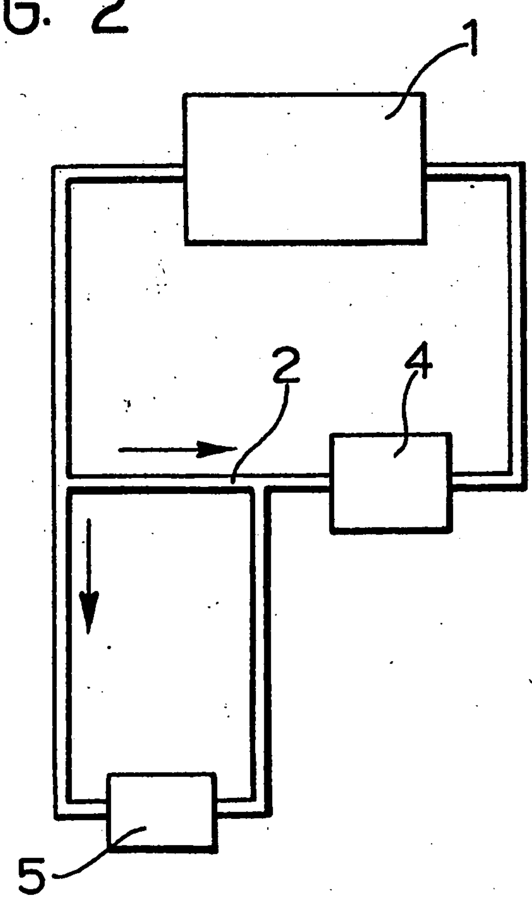


FIG. 3

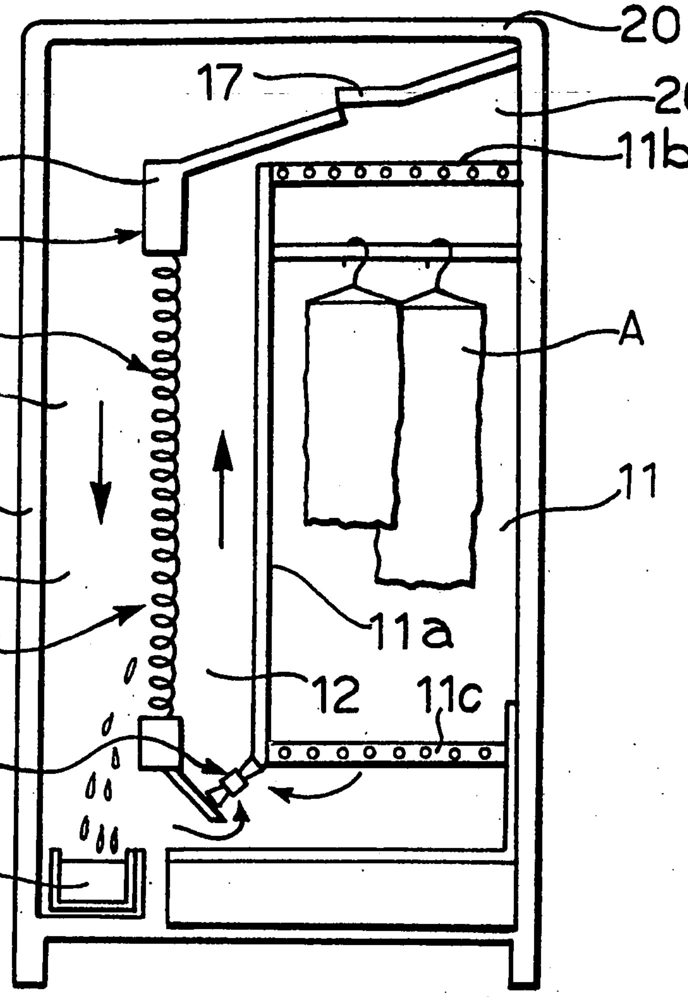
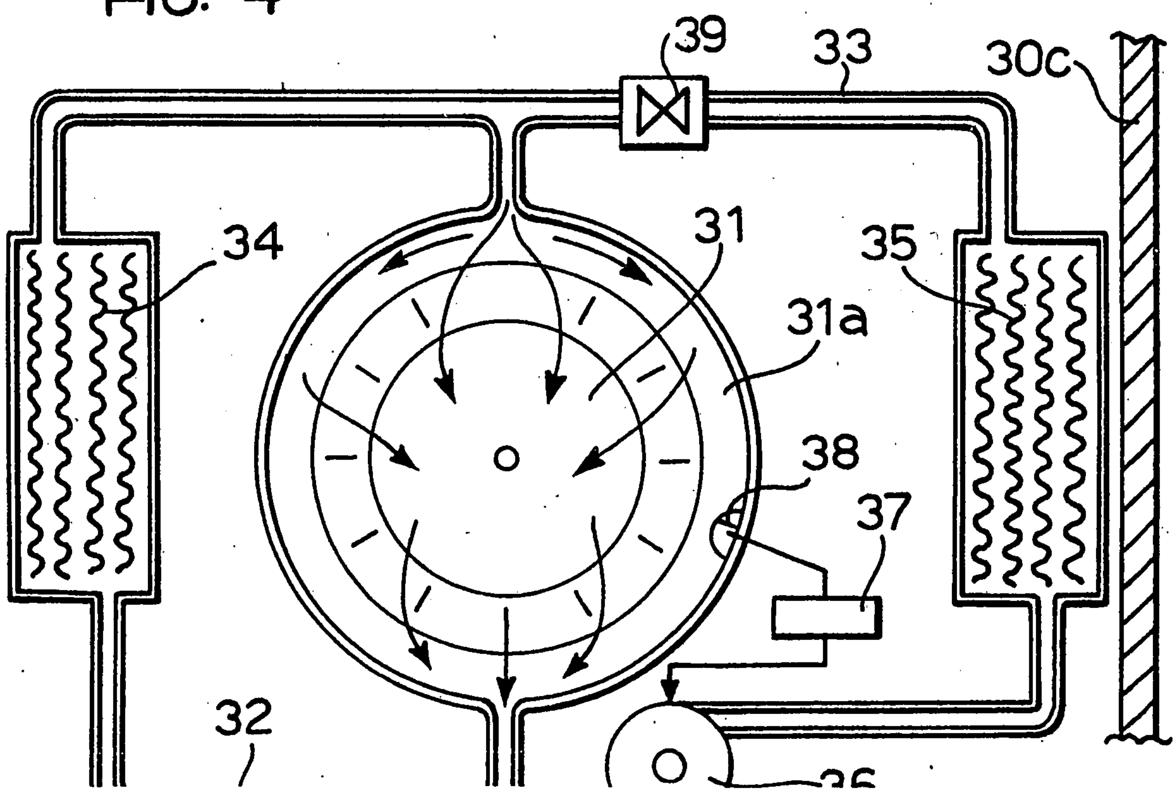

20
17
20a
21
11b
21b
14
A
20b
20c
11
13
11a
15
12
11c
16
13d

FIG. 4


39
33
30c
34
31
35
31a
38
37
32

SPECIFICATION

Drying apparatus

The present invention relates to drying apparatus and particularly to laundry driers of the type including a drying chamber connected in an air circulation circuit with which a heating element is associated.

In drying apparatus of the type specified above, the material to be dried, which is arranged in the drying chamber, is surrounded by a flow of hot air produced by the heating element.

In the drying chamber there therefore occurs a process of saturating the hot air which absorbs moisture at the expense of the sensible heat previously furnished to it by the heating element.

The moist air which leaves the drying chamber is directed back to the heating element. The air absorbs sensible heat from the heating element, its real temperature rises and it is again passed into the drying chamber in a closed circuit circulation system.

In drying apparatus of the type specified above, formed according to the known art, the overall thermodynamic yield of the drying cycle is thus rather low.

The object of the present invention is to provide drying apparatus, particularly a laundry drier, of the type specified above, which does not have the disadvantages indicated above and which is easy and economical to manufacture.

In order to achieve this object, the present invention provides drying apparatus of the type specified above, which is characterised in that the air circulation circuit has a branch loop outside the drying chamber with which are associated condensing means and means for selectively circulating the air into the branch loop when a predetermined humidity level is reached in the drying chamber.

By virtue of this characteristic, in the drying apparatus according to the invention the condensing means can be supplied with air which has reached a degree of saturation substantially corresponding to the maximum relative humidity achievable at the temperature of the drying chamber, significantly raising the overall thermodynamic yield of the drying cycle.

The invention will now be described by way of non-limiting example with reference to the appended drawings, in which:

Figure 1 illustrates the air circulation system in drying apparatus according to the invention in a simplified manner,

Figure 2 is a variant of Figure 1, and

Figure 3 and Figure 4 illustrate two different embodiments of drying apparatus according to the invention.

In Figures 1 and 2 a drying chamber shown as 1 is intended to receive the material, for example laundry, to be dried in operation of the drying apparatus.

The drying chamber 1 may be constituted either by a static casing or by a movable basket in the form of a rotary drum of the type presently used in driers and in washing/drying machines.

In Figure 1, the drying machine 1 is connected in an air circulation circuit comprising a main loop, indicated by 2, and a branch loop indicated by 3.

A heating element 4 is associated with the main loop 2 of the air circulation circuit.

Condensing means comprising, for example, a cooling element indicated by 5, are associated with the branch loop 3.

Preferably the heating element 4 and the cooling element shown as 5 constitute the condenser and the evaporator respectively of a single refrigeration system operating according to an inverse Carnot cycle or an absorption cycle.

The air circulation system illustrated in Figure 2 is substantially identical to that illustrated in Figure 1 with the single difference given by the fact that the heating element 4 is located between the downstream end of the branch loop 3 and the drying chamber 1.

Hence, in the system of Figure 1, the heating element 4 and the cooling element 5 are located in parallel with the drying chamber 1, in terms of the fluid flow. In the system of Figure 2, however, the heating element 4 is disposed in series with the cooling element 5 in terms of the fluid flow, moist air leaving the drying chamber 1 also being supplied directly to the heating chamber 4 through the single main loop 2.

Figure 3 shows an embodiment of drying apparatus for drying laundry in which the air circulation system is that illustrated in Figure 1.

In Figure 3 the parts corresponding to the elements illustrated in Figure 1 have therefore been indicated by the same reference numerals as in Figure 1 increased by 10.

The drying chamber, within which the material A to be dried is arranged, is in the form of a parallelpiped-form casing 11 mounted within a cabinet 20 the interior of which is subdivided by an intermediate partition 21 into two chambers 20*a* and 20*b*.

The chamber 20 encloses the drying chamber such that a wall 11*a* of the casing 11 and the surface of the partition 21 facing it define a main loop 12 of the air circulation circuit. An electric fan 16 may be associated with the main loop 12 to boost the air flow in the circuit when the air circulation produced by the thermosiphon effect is insufficient.

The ends of the main loop 12 are put in communication with the drying chamber 11 through respective perforated walls 11*b*, 11*c*.

The other surface 21*b* of the partition 21, together with the wall 20*c* of the cabinet 20 facing it, defines a branch loop 13 of the air circulation circuit.

The upstream end of the branch loop 13 is put in communication with the main loop 12 through an aperture across which is located a diaphragm valve 17 which opens as a result of slight pressure differences between the upstream and downstream sides of the valve itself.

The downstream end of the branch loop 13 is put in communication with the main loop 12

through an aperture of shaped section which acts exactly like an ejector, facilitating the return of the dehumidified air to the interior of the drying chamber 11.

In the embodiment illustrated in Figure 3, the central part of the partition 21 is constituted by a Peltier plate supplied from an external electric power source, not shown.

The hot side 14 of the Peltier plate faces the main loop 12 of the air circulation circuit and acts as a heating element.

The cold side 15 of the Peltier plate faces the branch loop 13 and acts as a cooling and condensing element.

The structure of the drying apparatus according to the invention, in which the heating element 14 and the cooling element 15 are disposed back to back, makes the use of a Peltier plate particularly advantageous. In addition to this, the ratio of the number of calories and the number of frigories produced by a plate of this type is typically about 2, which corresponds to about the optimum value for the operation of the drying apparatus.

On the bottom of the cabinet 20, within the branch loop 13, is located a vessel 13*a* for collecting the water formed by condensation on the cold side 15 of the Peltier plate.

Figure 4, in which the same reference numerals as in Figure 1 increased by 30 are used, relates to drying apparatus in which the drying chamber is in the form of a rotary basket 31, of the type currently used in driers and washing-drying machines.

A collecting chamber 31*a* is associated with the rotary basket 31 whereby the basket itself is connected in an air circulation circuit comprising a main loop 32 and a branch loop 33.

With the main loop 32 and the branch loop 33 are associated a heating element 34 and a cooling and condensing element 35 respectively which comprise plates of the type known in the art by the term "roll-bond".

Preferably the cooling element 35 is located adjacent a wall 30*c* of the casing of the drying apparatus which is sufficiently thin to allow heat exchange between the cooling element 35 and the external environment.

To the upstream end of the branch loop 33 is connected a motor driven fan 36 which drives the air flow in the loop itself. The fan 36 is activated by an electric control circuit 37 which is connected to a humidity and/or temperature sensor 33 disposed within the collecting chamber 31*a*. At the downstream end of the branch loop 33 is a non-return valve 39.

The operating cycle of the drying apparatus according to the invention includes two working phases.

In the embodiment illustrated in Figure 3, during a first operating phase, the air heated by the hot side 14 of the Peltier plate rises through the main loop 12 and enters the drying chamber 11 through the grill wall 11*b* which acts as a delivery diffuser. The hot air flows over the material A to be dried, absorbs moisture and is cooled. As a result of its increase in weight, the moist air tends to fall within the drying chamber towards the outlet wall 11*c* and is returned by convection (natural or forced by means of the electric fan 16) into the main loop 12.

In rising again through the main loop 12, the air absorbs sensible heat from the hot side 14 of the Peltier plate and again passes into the drying chamber 11.

The wall 11*a* of the drying chamber 11, as well as facilitating the air circulation by convection, prevents the ascending flow of hot air from mixing with the descending flow of cooler air.

When the optimum saturation level has been reached in the drying chamber 11, the steam overcomes the resistance of the diaphragm valve 17.

There is thus actuated the second operating phase of the drying apparatus in which the saturated vapour bled from the chamber 11 passes into the branch loop 13 where it is condensed by the cooling element 15.

The air, thus dehumidified, is then passed back into the cycle through the downstream end of the loop 13.

The diaphragm valve 17, which is actuated by the pressure gradient across the valve itself, acts as an automatic regulator adapting the bleed cross-section automatically to the free volume of the drying chamber 11 and to the quantity, the distribution, the moisture content and the nature of the materials to be dried.

This result cannot be achieved instead by using, in place of the valve 17, an aperture with a fixed, calibrated cross-section since, in realising the tapping action, this does not allow account to be taken of the different operating conditions which arise from variations in the quantity and quality of the material to be dried.

In the embodiment of Figure 4, the first operating phase described above (air circulation solely within the main loop 32 of the circuit) proceeds until the sensor 38 detects that the maximum relative-humidity level at the operating temperature of the drying chamber has been reached in the drying chamber 31 itself. This temperature is normally chosen in dependence on the maximum value allowed for the material A contained therein.

When the sensor 38 indicates that the saturation level indicated above has been reached, the control circuit 37 starts the second operating phase by activating the fan 36 which drives the air circulation passing out of the drying chamber 31 into the branch loop 33 wherein this moist air comes into contact with the cooling element 35.

The moisture in the air condenses and is collected in a container which can periodically be removed from the casing of the drying apparatus for disposal of the condensed water.

The non-return valve 39 situated at the downstream end of the branch loop 33 allows a pressure to be established in the branch loop 33 which is higher than that in the main loop 32 and in the drying chamber 31. This pressure difference

favours the condensation, possibly allowing one to do without the cooling element 35.

The alternation of the first working phase with the condensing phase may also be regulated in accordance with the time passed from the start of each operating phase by means of a timer associated with the control member 37.

The timer, which renders the use of the sensor 38 superfluous, is usually standardized in accordance with the average times needed to reach the maximum humidity level in the drying chamber and for the moisture to condense in the branch loop respectively.

As indicated previously, the cooling element 35, which preferably comprises plates of the "roll-bond" type, is located adjacent a thin wall 30*c* of the casing of the drying apparatus to facilitate heat exchange between the cooling element 35 and the external environment.

The arrangement described is particularly advantageous when the cooling element 35 and the heating element 34 are parts of the same refrigeration apparatus, of the heat-pump type.

During the first phase of the operating cycle (air circulation solely within the main loop of the circuit) the cooling element 35 can absorb heat from the external environment through the thin wall 30*c* and can transfer this heat to the heating element 34.

During the phase in which the vapour taken from the drying chamber 31 is condensed, however, the presence of a thin wall 30*c* facilitates the dissipation of the heat of condensation to the exterior, increasing the efficiency of the condensing action.

Naturally, the principle of the invention remaining the same, the actual details illustrated and described with reference to each of the embodiments of Figures 3 and 4 may also be freely applied to other embodiments. The general criteria of the embodiments illustrated in Figures 3 and 4 with reference to the air circulation system of Figure 1, may also be applied freely to the air circulation system illustrated in Figure 2 without thereby departing from the scope of the present invention.

CLAIMS

1. Drying apparatus, particularly laundry drying apparatus, of the type comprising a drying chamber connected in an air circulation circuit with which a heating element is associated, characterised in that the air circulation circuit has a branch loop outside the drying chamber with which are associated condensing means and means for selectively promoting the circulation of air in the branch loop itself when a predetermined humidity level is reached in the drying chamber.

2. Drying apparatus as claimed in Claim 1, in which a diaphragm valve is associated with the upstream end of the branch loop and opens as a result of a slight pressure difference between the upstream and downstream sides of the valve itself to allow the passage therethrough of the saturated vapour produced in the drying chamber, whereby the said condensing means work only on the vapour withdrawn.

3. Drying apparatus as claimed in Claim 1, including a pump member for driving the air circulation in the branch loop and a control member for selectively activating the pump member when the said humidity level is reached in the drying chamber.

4. Drying apparatus as claimed in Claim 3, in which the control member comprises a timer.

5. Drying apparatus according to Claim 3, in which a sensor is associated with the control member for detecting the temperature within the drying chamber.

6. Drying apparatus as claimed in Claim 3 or Claim 5, in which a sensor is associated with the control member for detecting the humidity level within the drying chamber.

7. Drying apparatus as claimed in Claim 3, in which a non-return valve is associated with the downstream end of the branch loop by virtue whereof the pump member produces an over-pressure in the branch loop itself.

8. Drying apparatus as claimed in Claim 1, in which the heating element and the condensing means constitute parts of a single refrigeration system operating according to an inverse Carnot cycle.

9. Drying apparatus as claimed in Claim 1, in which the heating element and the condensing means constitute parts of a single refrigeration system operating according to an absorption cycle.

10. Drying apparatus as claimed in Claim 1, comprising an outer casing having a thin wall and in which at least that part of the said branch loop including the condensing means extends adjacent the said thin wall.

11. Drying apparatus as claimed in Claim 1, in which the heating element and the condensing means comprise plates of the "roll-bond" type.

12. Drying apparatus as claimed in Claim 1, in which the heating element and the condensing means are constituted respectively by the hot side and the cold side of a Peltier effect plate.

13. Drying apparatus as claimed in Claim 1, in which the drying chamber is associated with a rotary basket.

14. Drying apparatus substantially as herein described with reference to, and as shown in, the accompanying drawings.

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